Design and Development of a Gripper System for an Indoor Service Robot

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Abstract

Service robot are designed to provide assistance in home environments, floor cleaning, material transporting and security purpose. This paper focuses on the design and development of a gripper system for a housekeeping robot 'ROOMBOT' to perform pick and place operations. A gripper with three degree of freedom is designed and developed and tested for pick and place of several objects.

Keywords : Roliot Geipprens, Robot Coutiol, Dinner Degree of Freedom.

I. Introduction

Robotic grippers find wide applications in industrial, medical and domestic use. Research in this area has been continuously evolving to provide more dexterous grippers which can mimic the human arm. Despite a number of prototypes of robotic gripper that have been developed in more than 20 years of research mainly in academic institutions among many others [1], effort is being devoted to seek and evaluate alternative solutions with sufficient dexterity to perform in any case non trivial operations on wide range of objects.

A gripper is a device which enables the holding of an object to be manipulated. The easier way to describe a gripper is to think of the human hand. Just like a hand, a gripper enables holding, tightening, handling and releasing of an object. Gripper is just one component of an automated system. A gripper can be attached to a robot or it can be part of a fixed automation system.

The basic operating principal of the gripper consists of three primary motions which is parallel, angular and toggle [2]. These operating principals refer to the motion of the gripper jaws in relation to the gripper body (refer Table 1). Rotary actuator is a device use to alternate the rotated position of an object. Just like the human wrist the actuator enables the rotation of an object, except that rotary actuators are available in a wide variety of models with different sizes, torques, and rotation angles.

The robot gripper can be divided into two sections, each with different function:

1. Arm and body – the arm and body of a robot are used to move and position parts or tools within a work envelope.

2. Wrist or end effectors – these parts are used to orient the parts or tools at the work location.

II. Design of the Gripper

The ROOMBOT robot is a housekeeping robot which was required to collect crushed paper in a controlled environment.

Identification of the object to be picked is accomplished by a hybrid vision system. Co-ordinates of the object to

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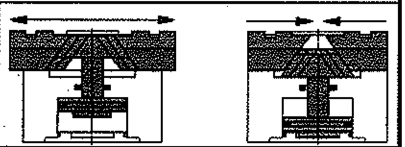
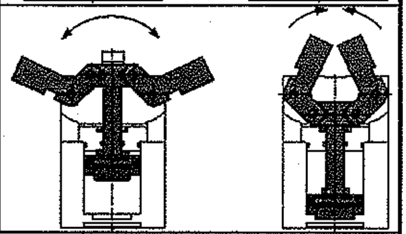
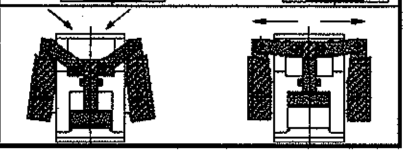
be picked will be provided by this system to the gripper. The mechanical design of the gripper is required to fulfill the interaction between the robot and the object in order to pick and place i.e. the object from the ground to the dustbin at the back of the robot. The initial target of object is identified as crushed paper. The movement mechanism of the gripper is simple and straightforward. It will react once the input is received from the vision system from the main controller.

Table 1 – Gripper Operating Principal

Operating Principal	Illustration
Parallel	
Angular	
Toggle	

Design Specification

The mechanical design of the gripper is inspired by the following issues [3-5, 7-13]:

a. The gripper should be able to manipulate object in round shape. The primary object to be grasped is a crash paper. The surface of a crash paper is rough and its shape being almost like round shape. The size targeted for the crash paper is 3cm to 8cm in diameter.

b. Grasping area is 25cm in front of the robot. The gripper should be able to extend to 25cm distance from the robot front body.

c. Grasping precision and position repeatability of the gripper is a requirement as memory of location is preset in controller.

d. Power consumption by the actuator should be small considering larger supply in need will increase the burden of the robot weight by installing larger battery cell. The strength of grasping should be enough to lift up a crash paper and hold it when transferring.

Mechanical Design

From the required design specification, the gripper is constructed first by using the Solid Works software to draft out the architecture of the whole gripper system. There are three parts in construction which is the base, the arm and the end effectors.

The base of the gripper system is constructed using L-shape aluminum bar with dimension of 9x8cm. One motor is use as the base driving actuator. The height of the gripper base is extended 3cm from ground by using cylinder screw. Figure 1 shows a drawing illustration of the base by using the Solid Works software.

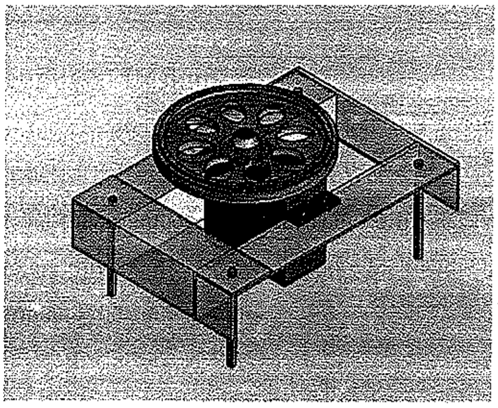


Figure 1 - Gripper base design drawing in Solid Works

The arm have two joints linking the arm and the wrist to the end effectors, labeled A and B in figure 2. Two motor is use to drive the first arm joint A, while the wrist only uses one of the standard servo motor for its drive. Two motor is use in for supporting and driving the first arm linked to the base.

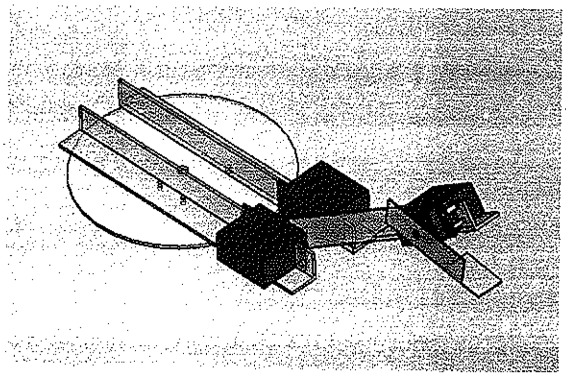


Figure 2 - Gripper arm and wrist design drawing in Solid Works

The design of the end effectors is using the pivoting or rotating jaws mechanism. This design is simple and only requires one actuator to drive the mechanism (refer figure 3). This design of mechanism requires sufficient accuracy in center of grasping of the object. Otherwise, the object may slip off when the gripper is closing the end effectors or the object may drop off from the end effectors in the middle of transferring the object to the dustbin.

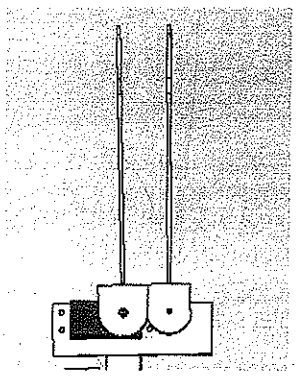


Figure 3 - End effectors design drawing in Solid Works

Gripper Degrees of Freedom

To locate an object in space, one need to specify the location of the selected object, thus it requires three pieces of information to be located as desired. These three pieces of information are the X, Y, and Z coordinates value [4]. With the three pieces of the information, the object location is specified. Hence, there is need for a total of six pieces of information to fully specify the location and orientation of the gripper.

The designed gripper only consists of 3 degrees of freedom, where it can only move along the X, and Y axes (refer figure 4). In this case, no orientation can be specified. All the robot can do is to pick up the object and move it to the dustbin. The orientation is always remains the same.

The end effectors are not considered as one of the degrees of freedom. All the gripper has this additional capability, which may appear to be similar to a degree of freedom. However, none of the movements in the end effectors are counted towards the gripper's degrees of freedom.

The weight limitation was important in construction of the gripper. The material used should have low density and good yield in strength properties and are easy to machine. Aluminum was choose as it criteria fits in. Aluminum is soft, durable, lightweight. It is ductile, and easily machined, cast and extruded. Hence, aluminum provides easy machinery and shaping with the tools, and allowing a high accuracy in part dimensions to be obtained. The aluminum sheet use has thickness of 2mm. This concludes that the whole gripper weight after the construction is 0.5kg.

Gripper Actuation

Parallax standard servo motor is selected as the gripper actuator because of its precision in positioning, and its weight is 45grams. The servo motor can produce torque up to 3.4kg-cm and it have small size casing with low price compare other similar servo motor that offer equivalent strength. One standard motor is use to drive the rotation of the base. Standard servo motor has limitation in rotation up to 180 degrees [6]. In that case, the base of the gripper only can turn in one side of area at 0 to 180 degrees. This rotation is sufficient to cover the area of object that could be detected in front of the robot.

Two motors are used to drive the first arm joint with the base. The weight induced over the end effectors are insufficient to be lifted up by only one motor torque. To avoid over current draw by the motor in producing sufficient torque, two motors are applied. The two motor sequences should be synchronized.

Gripper end effectors are driven by only one standard motor (figure 3). Two gears is used in series, and one of the gears is attached to the motor. When the motor rotate, the gear attach to the motor will rotate and drive the second gear in series with it to rotate in opposite direction. This effect will operate the end effectors to open wide up reaching to 180 degrees.

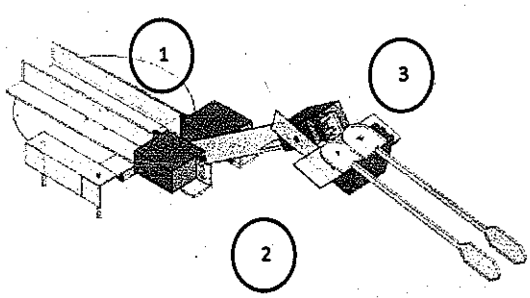


Figure 4 - Gripper design drawing – Isometric view

Drive and Control System

The gripper control program is written in assembly language, and running in Basic Stamp controller. The gripper program is executed together with mobile platform and ultrasonic sensor program in one processor. Another controller used was the servo controller. Servo controller can control up to 16 motor at one time. Servo controller communicates with Basic Stamp controller through serial cable. Signal is sent from Basic Stamp controller to the servo controller in pulse form.

The main features of the flow for the gripper program are shown in Figure 5. When the robot is powered up, the gripper will move to its standby position which is heading toward the back of the robot. When the main program is executed, the robot will move around with ultrasonic sensor as primary sensor to detect any object appears. When an object is been encounter, the vision system will activate to capture and recognize the encountered object. If an object is identified, the vision system will send input through the serial communication between the mobile platform main controllers and initiate the gripper system.

When the gripper is initiated, the base motor will rotate the body arm of the gripper towards the front side of the robot. Followed, the controller will instruct the first arm joint two motor to lift down the end effectors to a set height. At the set height the end effectors will open to 180 degrees wide. Again the gripper wrist will lower down bringing the end effectors closer to the object and perform the picking operation.

When the object is secure in the end effectors, the gripper is instructed by the controller to returns and place the object into the bin at the back of the robot before it reposition back to its standby position. After the operation of pick and place is completed, the robot will continue to move around in the environment.

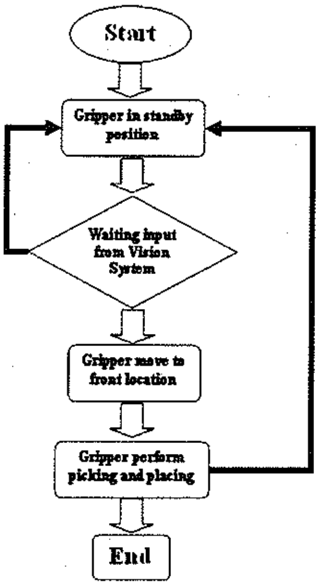


Figure 5 - Program Flow Chart

III. Experiments and Results

There were two types of experiments is done towards the designed gripper system to test it reliability and efficiency, the offline and online experiments. Offline testing is conducted on the gripper simulation without installation it onto the robot mobile platform. This is to test on the gripper functionality and define the coverage area of the gripper in picking object. A model of mobile platform is build to install the gripper system to perform the testing.

Online testing is conducted when the gripper system is assembled onto the mobile platform together with ultrasonic system and vision system. This testing conducted to test on the serial communication between the controller of PC and Basic Stamp which sending signal to trigger the gripper system when an object is been identified. Another testing is tested on the relocation of the Y-position when there is an input of Y-value from the vision system.

Discussion

From the testing, the result shows the gripper system is fully operate able. The average time for one cycle of pick and place operation is 12 seconds (Table 2). Once the gripper is triggered by the main controller, the gripper can operate to complete the task in that particular short of time period. This result shows the efficiency of the gripper in decreasing the operating time as less delay is created due to the pick and place action.

The gripper system can pick able to vary object. 5 type of objects is giving a testing which are the plastic bag, crash paper, empty bottle (500ml), carbonate drink can (325ml) and a small boxes. 4 of the item show pick able by the gripper. Empty bottle is unable to be picked because of its plastic body surfaces that give frictionless to the grasping force from the end effectors.

The gripper has a limitation in picking object with weight greater than 85grams. Object that weight over 85grams make the gripper to draw more current to produce more torque in lifting up the object and transferring it to the dustbin.

The communication between the Basic Stamp and the servo controller is via RS 232 serial protocol. The firmware number which replies by the servo controller when communication is established shows the version of the servo controller. After the confirmation of the firmware version, the baud rate is elevated to 38K4 baud. Now the servo motor can be control by entering the position command. Each position command is comprised of a heater, three parameters: C, R, PW, and a command terminator. The C parameter is a binary number 0-31 corresponding to the servo channel number. The R parameter is a binary number 0-63 that controls the ramp function for each channel. The PW parameter is the 16 bit Word that corresponds to the desired servo position.

When the robot detects an object, the distance for the robot to stop is 25cm away from the object regardless of which location of the object maybe laying in the Y-axis. The possible area of object fall in is coverage by the wide open angle of the gripper end effectors. Coordination of Y-position happen when the object fall in the camera coverage area where servoing is unable to perform to adjust the robot position to change the location of the object to the center in front of the robot.

Referring to Figure 6, the location Y1, Y2, and Y3 is pre-taught to the gripper. These three locations are set on the gripper base servo motor. Once there is an input from the vision system signaling the location of the object through the serial com, the gripper is activated and based on the data received from the vision system, the program command line will call to the desired preset location of the Y1, Y2, or Y3 and turn the gripper towards the location and perform pick and place.

IV. Conclusion

The gripper is designed with 3 degrees of freedom, build using light weight aluminum with total weight of 0.5kg, and drive by 5 standard servo motor. The gripper operation time is 12 seconds with pick able of vary object of plastic bag, small boxes, carbonate drink can and crashed paper.

The gripper also can manipulate in Y-position with the input from the vision system.

In conclusion to this project, the primary objective is achieved successfully. The crash paper selected as initial target of object is successfully picked able by the gripper in the range of 25cm distance apart from the front of the robot.

There still have a lot of improvement area in the gripper system that can be done to make it more reliable and effective. Any further improvement and upgrade on the version can still be carry on to perfected the system and commercialize for public usage.

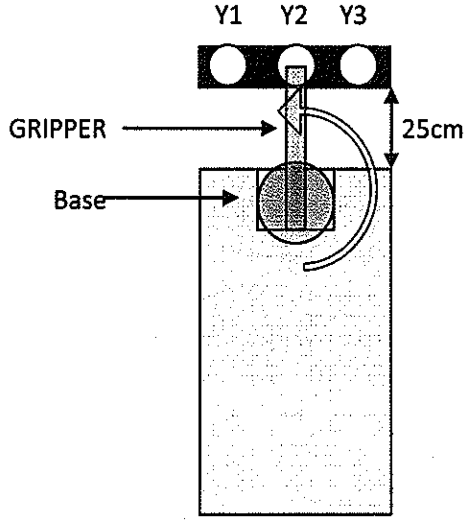


Figure 6 - Y-positioning of the gripper relative to the location of the objects.

Table 2 – Time taken for one completed cycle of pick and place

Trials	Time Taken (s)
1	12.64
2	12.76
3	12.60
Average	12.66

There are many design improvements that can be done in the proposed gripper system. The standard motor can be replaced by more better and powerful actuator to increase the torque and more degrees of freedom. A stepper motor can provide higher torque and 360 degrees of angle rotation compare with servo motor. So as, the area coverage by the gripper will extended more than just 25cm in radius.

The end effectors function can be improved by adding a degree of subsystem flexibility like variable jaw geometry featuring wide range gripper end effectors encompassing a board spectrum of object dimensions. Additional force sensor can be implemented on the end effectors to control the grasping force applied. It also can prevent the two finger of the gripper to over strain the object picked.

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